SECTION 8

UNCONFINED COMPRESSION TEST

References

- ASTM D 2166 – 16 - Standard Test Method for Unconfined Compressive Strength of Cohesive Soil.
- Bowles, Joseph E., Engineering Properties of Soils and Their Measurement (4th Edition)
- Lambe, T.W., Soil Testing for Engineers.
- ASTM D 6026 - 06 – using Significant Digits in Geotechnical Data

General Discussion

The primary purpose of this test is to determine the unconfined compressive strength, which is then used to calculate the unconsolidated undrained shear strength of the clay under unconfined conditions. According to the ASTM standard, the unconfined compressive strength (q_u) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In addition, in this test method, the unconfined compressive strength is taken as the maximum load attained per unit area, or the load per unit area at 15% axial strain, whichever occurs first during the performance of a test.

For soils, the undrained shear strength (s_u) is necessary for the determination of the bearing capacity of foundations, dams, etc. The undrained shear strength (s_u) of clay is commonly determined from an unconfined compression test. The undrained shear strength (s_u) of a cohesive soil is equal to one-half the unconfined compressive strength (q_u) when the soil is under the $\varphi = 0$ condition (φ = the angle of internal friction). The Mohr's circle construction for this test assumes that, (1) σ_3, the minor principal stress, is zero or atmospheric (any surface tension confinement is ignored) and (2) the angle of internal friction φ is zero.

The most critical condition for the soil usually occurs immediately after construction, which represents undrained conditions, when the undrained shear strength is basically equal to the cohesion (c). This is expressed as:

$$s_u = c = \frac{q_u}{2}$$

Then, as time passes, the pore water in the soil slowly dissipates, and the intergranular or effective stress increases, so that the drained shear strength (τ), given by $\tau = c + \sigma' \tan \varphi$, must be used. Where σ' = intergranular or effective pressure acting perpendicular to the shear plane; and $\sigma' = (\sigma - u)$, σ = total pressure, and u = pore water pressure; c' and φ' are drained shear strength parameters.

The unconfined compression test may be either strain-controlled or stress-controlled . The strain-controlled test is almost universally used, as it is simply a matter of attaching the proper gear ratio to a motor to control the rate of advance of a loading head (no timing is needed for the test). The test has been found to be somewhat sensitive to the rate of strain, but a strain rate between ½ and 2 percent/min appears to yield satisfactory results. One should use the higher strain rate with softer soils (which may require failure definition at a strain of 15 percent) and the lower strain rate (½ percent/min) for dry or stiff soil.

A stress-controlled test requires changing of loads and may result in erratic strain response and/or the ultimate strength falling between two stress increments. The loads are applied through a dead-load apparatus yoke. Some persons suggests developing the loads by adding water to a container attached to the yoke. In most cases, however, the dead load is simply a hanger to which masses are periodically added. Both methods, produce “shock” loading of the sample and are difficult to apply. For these several reasons, stress-controlled tests are seldom used in this or in any similar soil test

Equipment

Figure 8-1 showing the equipment used for unconfined compression test. The list of the equipment is as following:

- Compression device.
- Load and deformation dial gauges.
- Sample trimming equipment.
- Balance.
- Moisture can.



Figure 8-1: Equipment Used for Unconfined Compression Test.

Test Procedure

The test procedure is as following:

a. The soil sample should be extruded from Shelby tube sampler. A soil specimen should be cut so that the ratio (L/d) is approximately between 2 and 2.5, where L and d are the length and diameter of soil specimen, respectively.

b. The exact diameter of the top of the specimen should be measurd at three locations 120° apart, and then the same measurements should be made on the bottom of the specimen. The measurements should be averaged and the average must be recorded as the diameter on the data sheet.

c. The exact length of the specimen should be measured at three locations 120° apart, and then the measurements should be averaged and the average should be recorded as the length on the data sheet.

d. The sample should be weighed and recorded on the data sheet.

e. The deformation (L) corresponding to 15% strain (ε) should be recorded.

$L = Strain\ (\varepsilon) \times L_0$

Where L_0 = Original specimen length (as measured in step c).

f. The specimen in the compression device should be placed carefully and it should be centered on the bottom plate. If the ends are not exactly perpendicular to the specimen axis, the early part of the stress-strain curve will be flat (until the full sample area contributes to stress resistance, strains will be too large for the nominal stresses computed). The device should be adjusted so that the upper plate just makes contact with the specimen and the load and deformation dials should be set to zero.

g. The load should be applied so that the device produces an axial strain at a rate of 0.5% to 2.0% per minute, and then the load and deformation dial readings should be recorded on the data sheet at every 20 to 50 divisions on deformation the dial.

h. The load should be kept applying until:

(1) The load (load dial) decreases on the specimen significantly,

(2) The load holds constant for at least four deformation dial readings, or

(3) The deformation is significantly past the 15% strain that was determined in step e.

j. A sketch should be drawn to depict the sample failure.

k. The sample from the compression device should be removed and then a sample should be obtained for water content determination.

Data Analysis

The data recording and computation procedure are as under:

a. The dial readings should be converted to the appropriate load and length units, and these values should be entered on the data sheet in the deformation and total load columns. (Confirm that the conversion is done correctly, particularly proving dial gage readings conversion into load).

b. The sample cross-sectional area A_0 should be computed as,

$$A_0 = \frac{\pi}{4} \times d^2$$

c. The strain ε should be computed,

$$\varepsilon = \frac{L}{L_0}$$

d. The corrected area should be computed,

$$A' = \frac{A_0}{1 - \varepsilon}$$

f. Using A′, the specimen stress σ should be computed,

$$\sigma = \frac{P}{A'}$$

(One must be careful with unit conversions and should use constant units).

g. The water content, w% should be computed.

h. The stress versus strain should be plotted. q_u should be shown as the peak stress (or at 15% strain) of the test. It must be made sure that the strain is plotted on the abscissa (See the worked out example).

j. Mohr's circle should be drawn using q_u from the last step and the undrained shear strength, s_u = c (or cohesion) = $q_u/2$ should be shown (See the worked out example).

Significant Figures

1. The value of water content should be expressed to the nearest 0.1.
2. The value of axial strain should be expressed to 3 significant digits.
3. The value of stress or pressure should be expressed to 3 significant digits.

WORKED OUT EXAMPLE

Unconfined Compression Test

Test Serial No. : **08**

Date Tested: **January 12, 2009**

Tested By: _____

Project Name: **Airport Road – Rokeya Sharoni Link Road Project**

Location : **Jahangir Gate**

Sample Number: **B-1, U - 2**.

Visual Classification of Soil: **Silty clay**.

Job No: **2** Sample Depth: **1.5 m**.

Initial diameter (d_0) = **1.5 inch**

Initial area (A_0) = **1.767 inch^2**

Initial length (L_0) = **3 inch**

Initial volume (V_0) = **5.3 inch^3**

Moisture Content Determination

Tare No	**402**
Wt of tare	**7.32 gm**
Wt of tare + wet sample	**176.81 gm**
Wt of tare + dry sample	**145.32 gm**
Wt of water	**31.49 gm**
Wt of dry soil	**138 gm**
Moisture content, W%	**22..8**

Unconfined Compression Test Data

(Load Dial: 1 unit = 0.3 lb; Deformation Dial: 1 unit = 0.001inch)

Load Dial	Axial Load, P (lb)	Displacement Dial	Total Displacement (in)	Unit Strain	Corrected Area (in^2)	Stress, σ (psi)	Shear Stress (psi)
0	**0**	**0**	**0**	**0**	**1.766**	**0.00**	**0.00**
1	**0.3**	**3**	**0.003**	**0.001**	**1.768**	**0.17**	**0.08**
1.5	**0.45**	**6**	**0.006**	**0.002**	**1.770**	**0.25**	**0.13**
2	**0.6**	**9**	**0.009**	**0.003**	**1.772**	**0.34**	**0.17**
2.5	**0.75**	**12**	**0.012**	**0.004**	**1.773**	**0.42**	**0.21**
5	**1.5**	**15**	**0.015**	**0.005**	**1.775**	**0.85**	**0.42**
9	**2.7**	**30**	**0.03**	**0.01**	**1.784**	**1.51**	**0.76**
15	**4.5**	**45**	**0.045**	**0.015**	**1.793**	**2.51**	**1.25**
22	**6.6**	**60**	**0.06**	**0.02**	**1.802**	**3.66**	**1.83**
25	**7.5**	**75**	**0.075**	**0.025**	**1.812**	**4.14**	**2.07**
35	**10.5**	**90**	**0.09**	**0.03**	**1.821**	**5.77**	**2.88**
45	**13.5**	**120**	**0.12**	**0.04**	**1.840**	**7.34**	**3.67**
52	**15.6**	**150**	**0.15**	**0.05**	**1.859**	**8.39**	**4.20**
55	**16.5**	**180**	**0.18**	**0.06**	**1.879**	**8.78**	**4.39**
58	**17.4**	**210**	**0.21**	**0.07**	**1.899**	**9.16**	**4.58**
60	**18**	**240**	**0.24**	**0.08**	**1.920**	**9.38**	**4.69**
60	**18**	**270**	**0.27**	**0.09**	**1.941**	**9.27**	**4.64**
59	**17.7**	**300**	**0.3**	**0.1**	**1.963**	**9.02**	**4.51**
58	**17.4**	**330**	**0.33**	**0.11**	**1.985**	**8.77**	**4.38**

Sample Calculations (For Last Reading)

Load dial reading = 58

Axial load = 58 x 0.3 (load factor) = 17.4 lb

Displacement dial reading = 330

Total Displacement or change in length, L= 330 x 0.001 = 0.33 inch Initial length, L0 = 3 inch

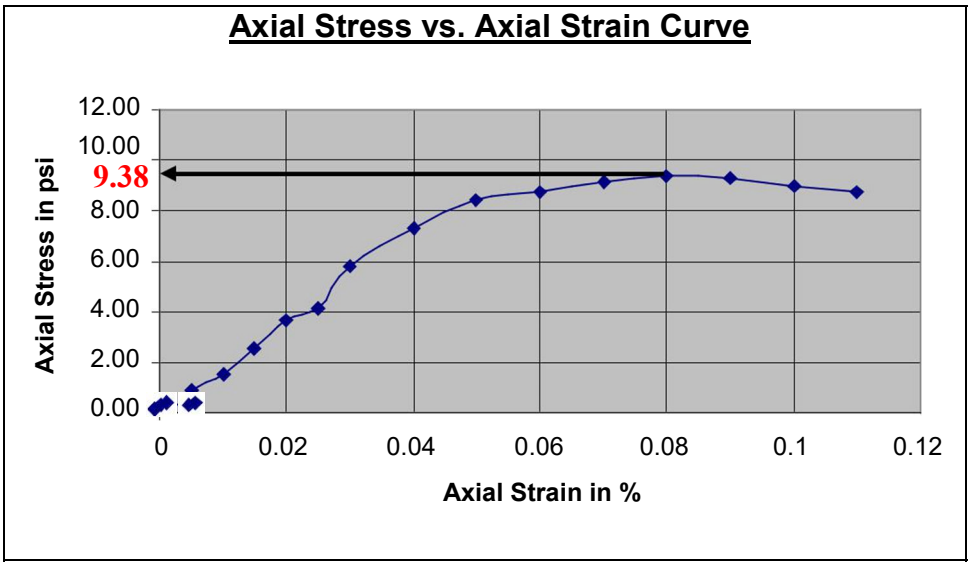
Unit strain, ε = L / L_0 = 0.33 / 3 = 0.11

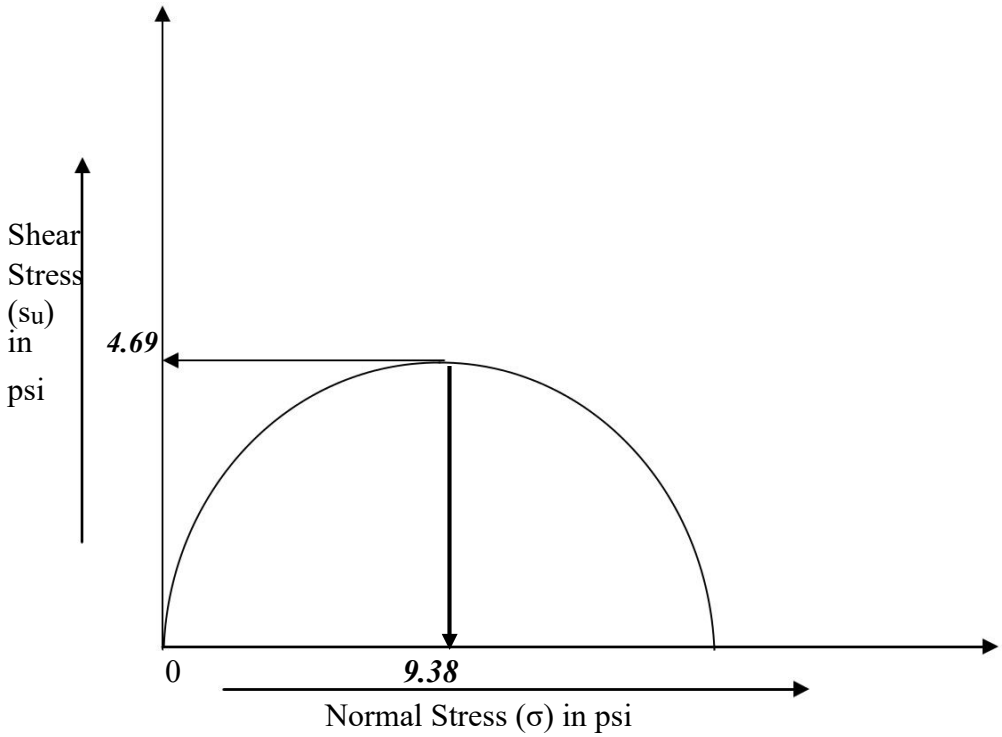
Initial area (A_0) = 1.767 inch^2

Corrected area, $A' = \frac{A_0}{1-\varepsilon}$ = 1.767 / (1 – 0.11) = 1.985 inch^2

Stress, σ = load / corrected area = 17.4 / 1.985 = 8.77 psi

Shear Stress, $\tau = \sigma / 2$ = 8.77 / 2 = 4.38 psi





From the stress-strain curve and Mohr's circle:

Unconfined compressive strength (q_u) = 9.38 psi Cohesion (c) = 4.69 psi